Reconstructing the High Mass Dimuon Continuum using PYTHIA Simulation as a Baseline for Data Analysis at PHENIX

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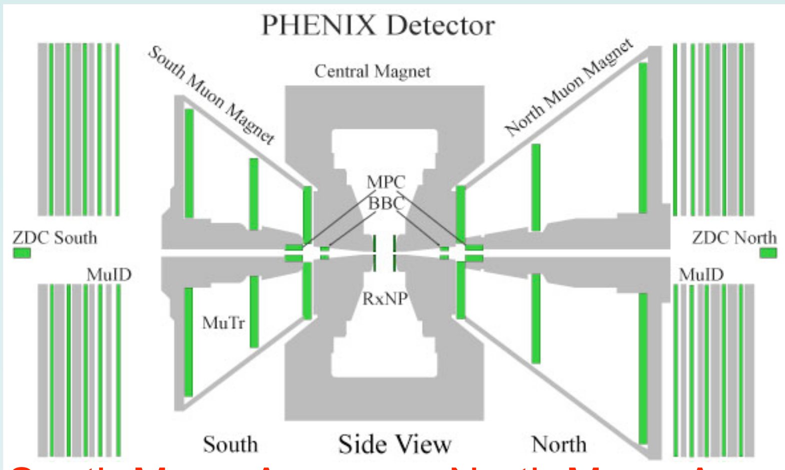
Introduction

Dilepton pairs produced from nucleus-nucleus collisions at the Relativistic Heavy Ion Collider (RHIC) are important probes for studying the properties of the hot and dense matter state created from these collisions, as they are not affected by the strong interactions. In the high mass region, between the J/Ψ and Υ resonances, open charm and open bottom decays dominate the dilepton mass spectra. An additional component of the high mass dilepton spectra is from the Drell-Yan process, which contributes an order of magnitude less than open heavy meson decays. Here, a status update of reconstructing the dimuon continuum in the high mass range between 4 and 8 GeV/c^2 using simulated events generated with PYTHIA within the PHENIX muon arms acceptance (1.2 < |η| < 2.2) is presented, including contributions from open charm, open bottom, and Drell-Yan processes. Additionally, the J/Ψ, Ψ', Υ, Υ', and Υ'' resonance states are generated so that the mass spectra between 2 and 12 GeV/c^2 can be compared with data. These results will be used to analyze the dimuon continuum components from p+p data at $\sqrt{s_{NN}}$ = 200 GeV taken in 2009 at RHIC.

PHENIX Detector

PHENIX (Pioneering High Energy Nuclear Interaction eXperiment), at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory, is equipped to measure photons, hadrons and electrons in the Central Arm detectors (|η| < 0.35) and muons in the Muon Arm detectors (1.1 < |η| < 2.2). The Muon Arm detectors consists of both a Muon Tracker to measure the momentum of the muons and a Muon Identifier system, [1] as shown below.



South Muon Arm: -2.2 < η < -1.2 North Muon Arm: 1.2 < η < 2.2

Simulation Setup

- Events were generated in PYTHIA 6.421 using a leading order parton distribution function (CTEQ5L), and subsequently run through the PHENIX simulation chain (PISA) to account for detector acceptance and efficiency.
  - All J/Ψ, Ψ', and Υ states, in addition to Drell-Yan, were forced to decay through dimuon channels, and open charm & open bottom states through semi-muonic channel.
- The Beam Beam Counter (BBC) z-vertex distribution from data was used to generate the particle's vertex.
- To calibrate the simulation software, the BBC z-vertex resolution was smeared by ±2 cm during event reconstruction in order to achieve the J/Ψ mass resolution from data.
- The following parameters were used in the PYTHIA simulation

	J/Ψ	Ψ'	Υ_{1s}	Υ_{2s}	Υ_{3s}	Open charm	Open bottom	Drell-Yan
# of events generated	1M	1M	1M	1M	460k	1.97M	1M	1M

Status of Dimuon Reconstruction & Comparison with Data

- An exponential fit function was used to extract the line shape for each of the components. Fit ranges for open charm, open bottom, and Drell-Yan were 2-5 GeV/c^2, 4-12 GeV/c^2, and 4-12 GeV/c^2, respectively. All parameters were allowed to vary. Fig. 1 shows simulation results and exponential fit functions in red.

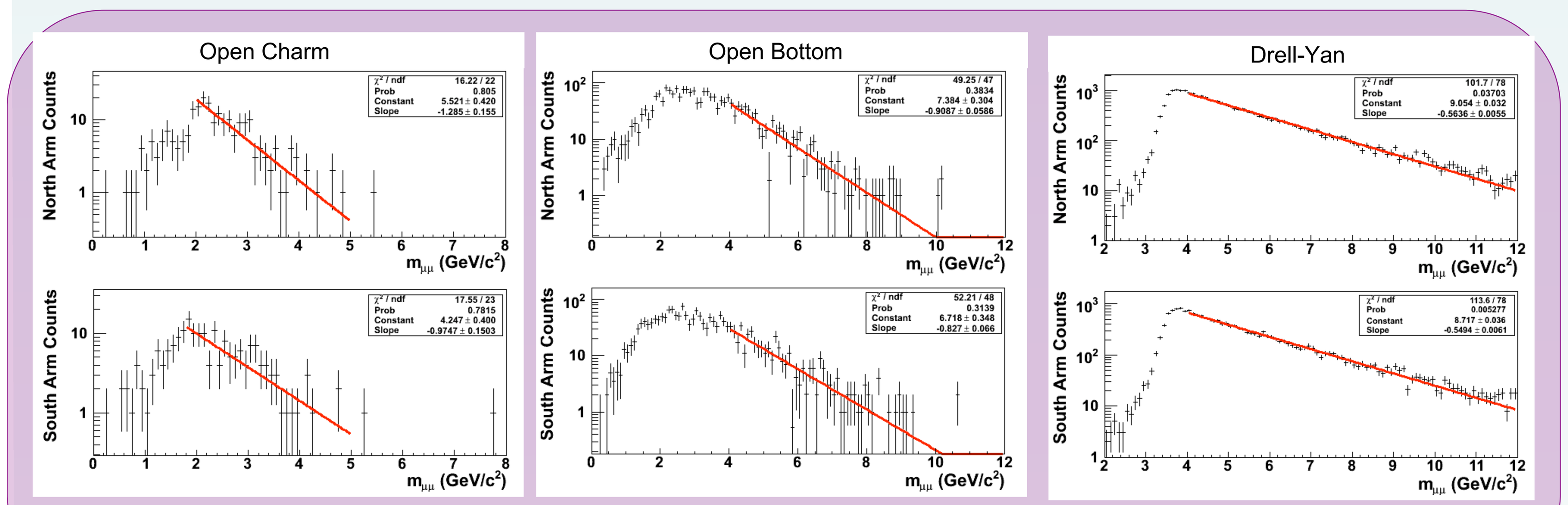


Figure 1: Dimuon invariant mass plots of simulated open charm (left), open bottom (center), and Drell-Yan (right) processes. Red lines show exponential fits.

- The continuum line shapes were scaled to match data using a triple exponential fit function:

$$\frac{dN}{dm_{\mu\mu}} = p_0\frac{dN_{c\bar{c}}}{dm_{\mu\mu}} + p_1\frac{dN_{b\bar{b}}}{dm_{\mu\mu}} + p_2\frac{dN_{DY}}{dm_{\mu\mu}}$$

where p_0, p_1, and p_2 are fitting parameters and $dN_{cc}/dm_{\mu\mu}$, $dN_{bb}/dm_{\mu\mu}$, and $dN_{DY}/dm_{\mu\mu}$ are the line shapes of open charm, open bottom, and Drell-Yan, respectively. All slopes were fixed and fitting parameters were allowed to vary.

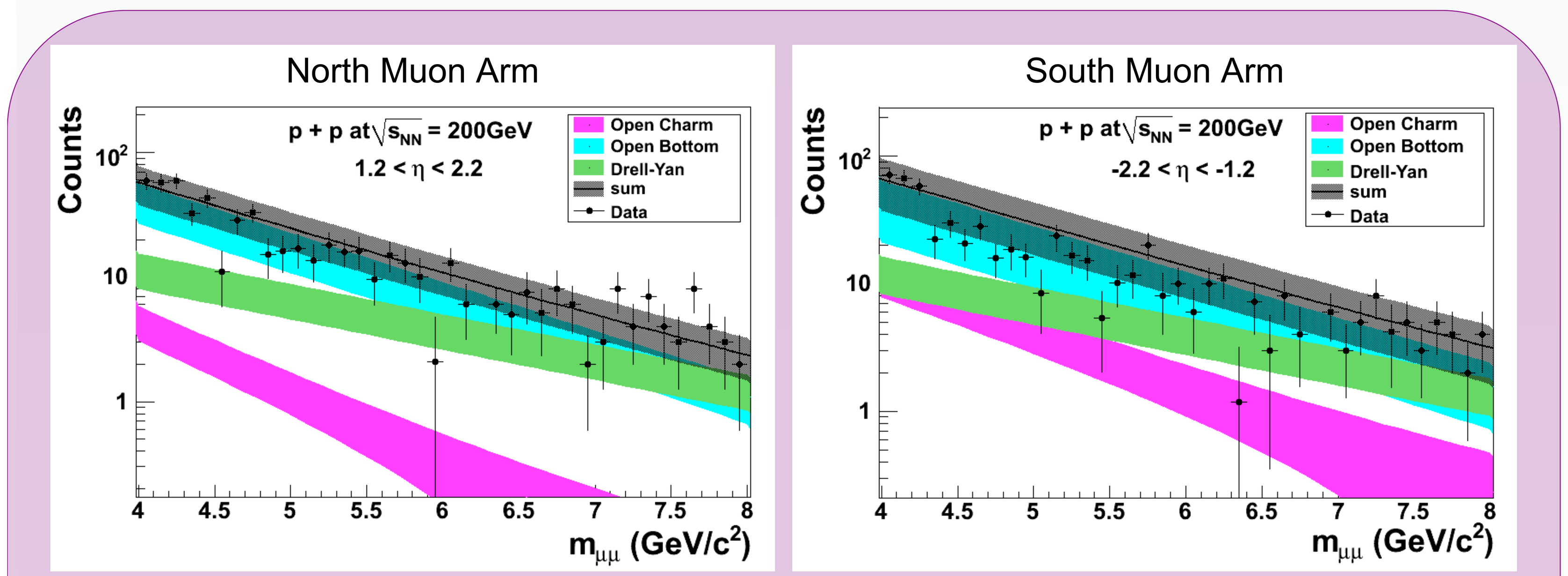


Figure 2: Invariant mass plot showing both simulated continuum compared with data. The continuum line shapes were scaled to match data using a triple exponential fit function. Bands include error from both scaling parameters and slope.

- The invariant mass spectra were generated from data using like-sign background subtraction.

$$S = N_{+-} - 2\sqrt{(N_{++})*(N_{--})}$$

Where S is the signal, N_{+-} are the number of unlike-sign pairs, and N_{++} and N_{--} are the number of positive and negative like-sign pairs, respectively.

- The invariant mass spectra from the simulated continuum and J/Ψ, Ψ', and Υ_{1s}, Υ_{2s}, Υ_{3s} states were reconstructed between 2 and 12 GeV/c^2.
- J/Ψ and Ψ' line shapes were scaled to values obtained from double gaussian + exponential fit to data; [2] and Υ_{1s}, Υ_{2s}, Υ_{3s} were scaled to J/Ψ using the ratio of cross sections to that of J/Ψ. All cross sections were taken from. [3]

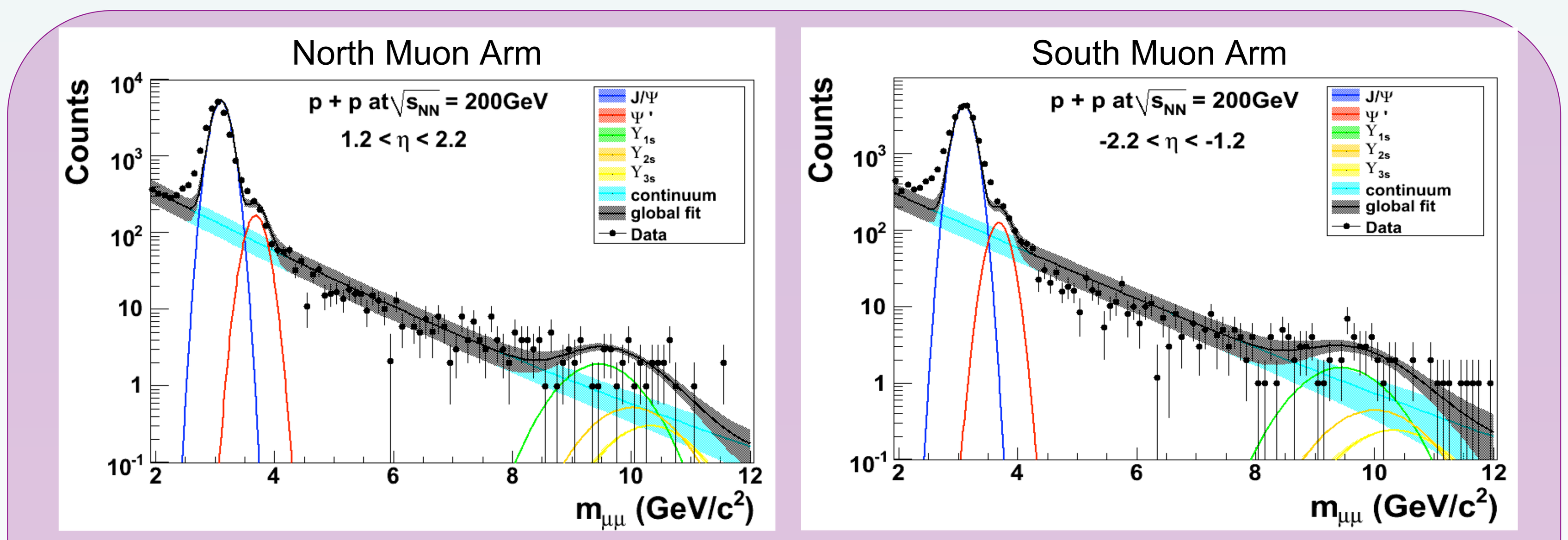


Figure 3: Dimuon invariant mass plots covering the full mass range from 2 - 12 GeV/c^2 comparing data with the simulated dimuon cocktail.

Summary & Outlook

- The high mass dimuon continuum was reconstructed between 4 and 8 GeV/c^2 using events generated in PYTHIA and run through the PHENIX simulation chain software.
- The results presented here will be used to as a baseline to study data from Au+Au collisions at 200GeV taken in 2010, specifically, how the dimuon yield in the high-mass continuum range is modified in the presence of a medium.
- Future upgrades at PHENIX should greatly improve the ability to separate the individual processes, thus, improve our understanding of the underlying physics in heavy ion collisions.

[1] H. Akikawa et al., Nuclear Instruments and Methods in Physics Research A 499 (2003) 537–548.
[2] A. Adare et al., PRL **98**, 232002 (2007).
[3] A.D. Frawley et al., Physics Reports 462 (2008) 125–175.

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